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ANNUAL PROGRESS REPORT

SNOW MANAGEMENT AND MELTWATER ENHANCEMENT

PROJECT 3.2-3

CANADA/SASKATCHEWAN ECONOMIC & REGIONAL DEVELOPMENT

ASSISTANCE (ERDA) FUND

Report prepared

by

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EXECUTIVE SUMMARY

The 1987-88 winter season was characterized by very low snowfall at all study sites. Snowcover water equivalents (SWE) on many of the 'unmanaged' plots at the time of melt were less than 50mm.

Because of very poor stubble stands and low snowfall amounts, the deflector strips showed little effect on increasing accumulation. In anticipation, snow fences at Kerrobert (Reynold's) and Saskatoon were erected in order to capture an appreciable amount of snow. The average SWE on the subsoiled field on the Wright farm was approximately 47mm. On snow fenced areas, the maximum snowcover ranged from 48 to 140mm.

Infiltration for shallow covers was approximately equal to SWE. In ripped and cracked soils, 45 to 49mm of SWE resulted in 105 to 137mm infiltration into the rips. As to depth of penetration, the findings support a recommended depth of approximately 500mm. As to width, the findings and model analysis suggest the line spacing between 0.9 to 1.3m is adequate to allow efficient meltwater augmentation from stubble snow management practice.

Patchy snow cover at the Kerrobert sites, resulted in patchy growth. Yield data at the Kerrobert sites (where snow had accumulated) suggest that for each 25mm of water produced an additional 190 kg/ha of spring wheat.

Similarly at sites at Swift Current, little snow accumulation resulted in low overwinter gains. The 1987 subsoiled treatments lost most of the overwinter precipitation gained. As a result, there was no significant yield response to snow management practices or effect of slope position, however, observations indicated that yields from Kello-Bilt treatments were higher than the Hubbee treatment. Analysis of core bulk densities in May 1988, indicated no effect of subsoiling treatments on soil bulk densities. However, using standard cone pentrometer readings, there were significant differences between differences to a depth of 40cm.

Measurements of energy requirements indicated fuel consumption increased rapidly with subsoiling depth. Fuel consumption, forward speed, engine rpm and slippage was monitored for the Kello-Bilt and Hubbee subsoilers.

Presentations were made to farm groups at Moose Jaw and Kyle. An update on the factsheet in co-operation with Professor Mike Grievers was prepared. Numerous requests for information has been requested including a recent interview with the Western Producer.

ACKNOWLEDGMENTS

The authors of this report would like to acknowledge the financial support received from the Saskatchewan/Canada Economic and regional Development Assistance (ERDA) Agreement that made this study possible. The co-operation of D. Sutherland of Richlea, R. Reynolds and L. Wright of Kerrobert and J. Warkentin of Swift Current, owners of land on which the studies were implemented, is gratefully appreciated. The technical support of Dan Ulrich and D. Reimer of Agriculture Canada Research Station at Swift Current, D. Bayne and R. Granger of the University of Saskatchewan and K. Best, K. Wallace, Ross MacKay and Newell Hedstrom of the National Hydrology Research Institute who diligently worked in adverse sub-zero temperatures to instrument the sites is gratefully appreciated.

A hearty thank you to Kello-Bilt Industries for the use of a Series 5000 Model 330 subsoiler available for the study. Also thanks to Hoechst Canada for Hoe-Grass II for general in-crop weed control and for Decis for grasshopper control.

SNOW MANAGEMENT AND MELTWATER ENHANCEMENT

PROGRESS REPORT - March, 1989

PROJECT OBJECTIVES:

1. To study the effects on meltwater enhancement by such tillage practices as spiking, paraploving and subsoiling or deep ripping under the stubble management treatments of tall stubble and trap strips.

2. To establish the potential of managing snow by stubble management practices for meltwater augmentation on severely cracked soils.

3. To evaluate the application of subsoiling practices for establishing and increasing the productivity of hill tops.

4. To evaluate the effects on yield of increased water additions obtained with the combination of practices listed in item (1) and in cracked soils (item 2), as compared with those obtained under conventional, uniform stubble.

5. To examine the effects of different tillage and snow management practices in surface runoff and groundwater recharge.

6. To study the effects of the depth and spacing of different subsoiling treatments on snow water infiltration and distribution in the root zone and the energy requirements for installation and to establish criteria for system design.

7. To obtain data on the life-expectancy or durability of the tillage treatment in improving the infiltration characteristics of frozen soils.

PROGRESS:

Based on the action plan submitted in the first annual progress report (February, 1987), this report will summarize the results from the 1987-88 field season based on studies conducted at field sites established at Kerrobert, Richlea, Swift Current and Saskatoon. The studies conducted at Kerrobert, Richlea and Saskatoon had the following specific objectives:

RICHLEA, KERROBERT AND SASKATOON SITES

1. **Richlea (D. Sutherland Farm)**

   Objectives:

   (1) To study the infiltration characteristics of severely cracked, heavy clay (Sceptre) soils, and

   (2) To study the effects of "trap strips" on meltwater augmentation.

2. **Kerrobert (Ritz Reynolds Farm)**

   Objectives:

   (1) To study the effects of different subsoiling treatments on meltwater infiltration,

   (2) To study the effects of "combined" snow management and subsoiling practices on meltwater enhancement and soil water augmentation,

   (3) To obtain information on the longevity of the effects of a subsoiling treatment in infiltration, and the depth and spacing of different treatments for optimum soil water intake and distribution, and,

   (4) To study the effects on yield of subsoiling and snow management practices.

3. **Kerrobert (Lyle Wright Farm)**

   Objectives:

   (1) To study the effects of a subsoiling treatment on surface runoff from snowmelt.

4. **Saskatoon (Kernan Crop Research Farm)**

   Objectives:

   (1) To study the 'areal' infiltration of meltwater and runoff in a subsoil area.

The 1987-88 winter season was characterized by very low snowfall at all study sites. Snowcover water equivalents (SWE) on many of the "unmanaged" plots at the time of melt were less than 50 mm. Only at Kerrobert (Reynold's farm) and Saskatoon where snow fences had been erected were there appreciable accumulations (Table 1). On the subsoiled field on the Wright farm the average SWE was approximately 47 mm; on the Reynolds farm the depth of cover was highly variable ranging from large, snow-free patches to a maximum accumulation with a SWE of 188 mm on one of the fenced areas; and at Saskatoon the water equivalent of the snowcover ranged from 48 to 140 mm. The wide spatial variablity in snowcover negated the possibility of obtaining representative "areal" data of the SWE-fertilizer-yield interaction on the different subsoiling treatments.

At Richlea, the total snowcover water equivalent available for infiltration resulted from snowfall which occurred just prior to the melt; hence the deflector strips showed little effect in increasing accumulation.

Infiltration Into Cracked and Subsoiled Soils

Table 1 gives the snowcover water equivalent (SWE), the snowmelt infiltration (INF), and the depth of water penetrated into the frozen soil (d) monitored at the different sites in 1988. The relative locations of the measurement sites are shown in the schematic diagrams (Figs. 1, 2, 3 and 4). The data in Table 1 are consistent with the findings of snowmelt infiltration to undisturbed, cracked and subsoiled soils reported by Gray and Granger (1985). Namely, they show:

1. On Undisturbed Stubble:
    (a) For shallow snowcovers, infiltration amounts approximately equal to the SWE; for deep snowcovers, INF << SWE.
    (b) Meltwater penetrates a frozen soil only to shallow depths (range 160 to 560 mm, average = 356 mm).
2. In Cracks and Rips
    (a) Large amounts of infiltration. In several cases INF exceeds SWE and this is attributed flow of meltwater along the line and to direct entry of runoff into the surface opening, the undisturbed soil between the openings acting as a contributing area of infiltrating water. The effect is most evident at the Wright and Reynolds' farms on plots which were subsoiled on a line spacing of 1.4 m with a Kello-bilt in the fall of 1986. At Wrights' snowcover water equivalents of 45 and 49

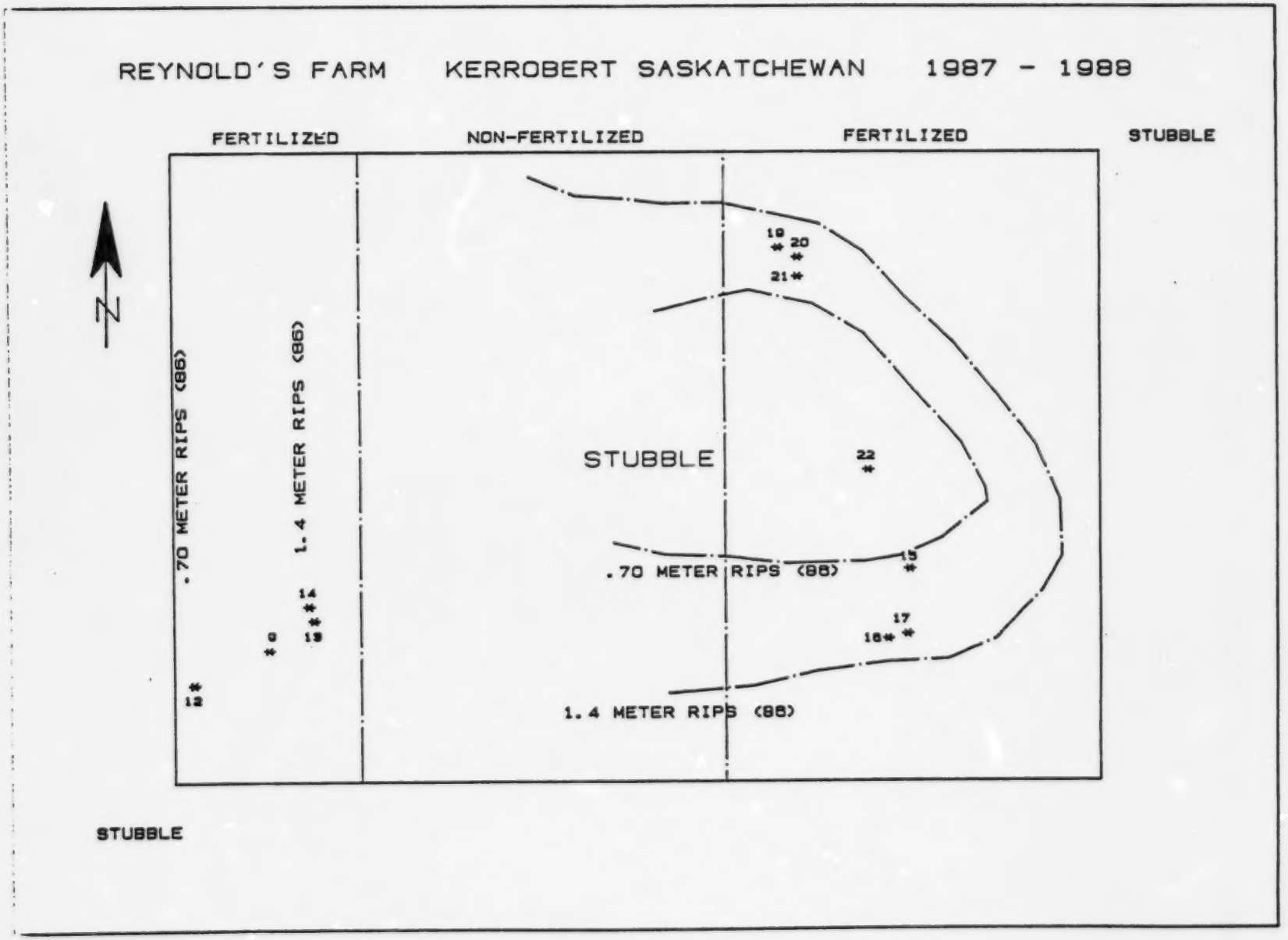

Figure 1: Soil moisture monitoring sites - Reynolds Farm (west) Kerrobert, 1987/88.

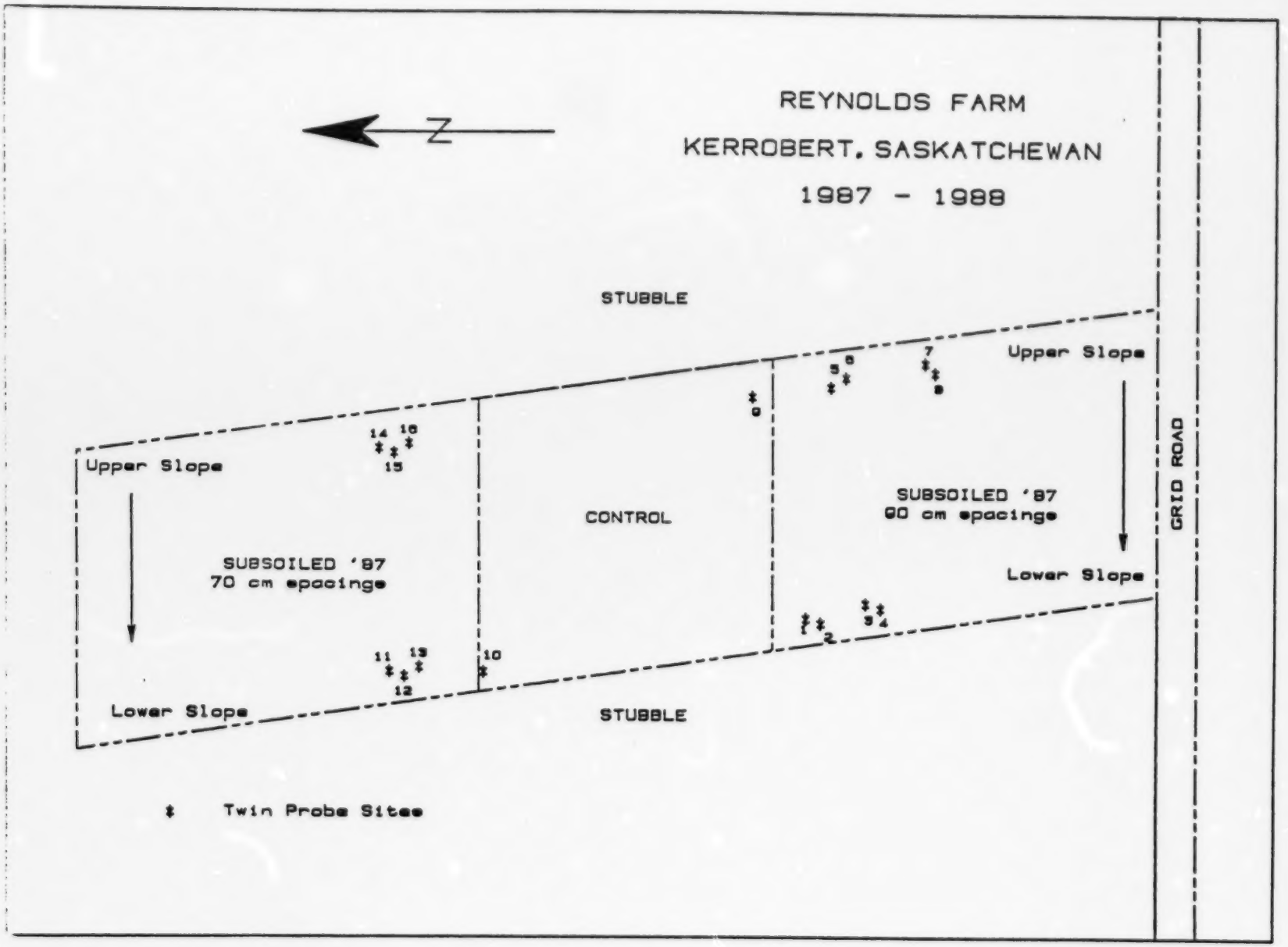

Figure 2: Soil moisture monitoring sites - Reynolds Farm (east) Kerrobert, 1987/88.

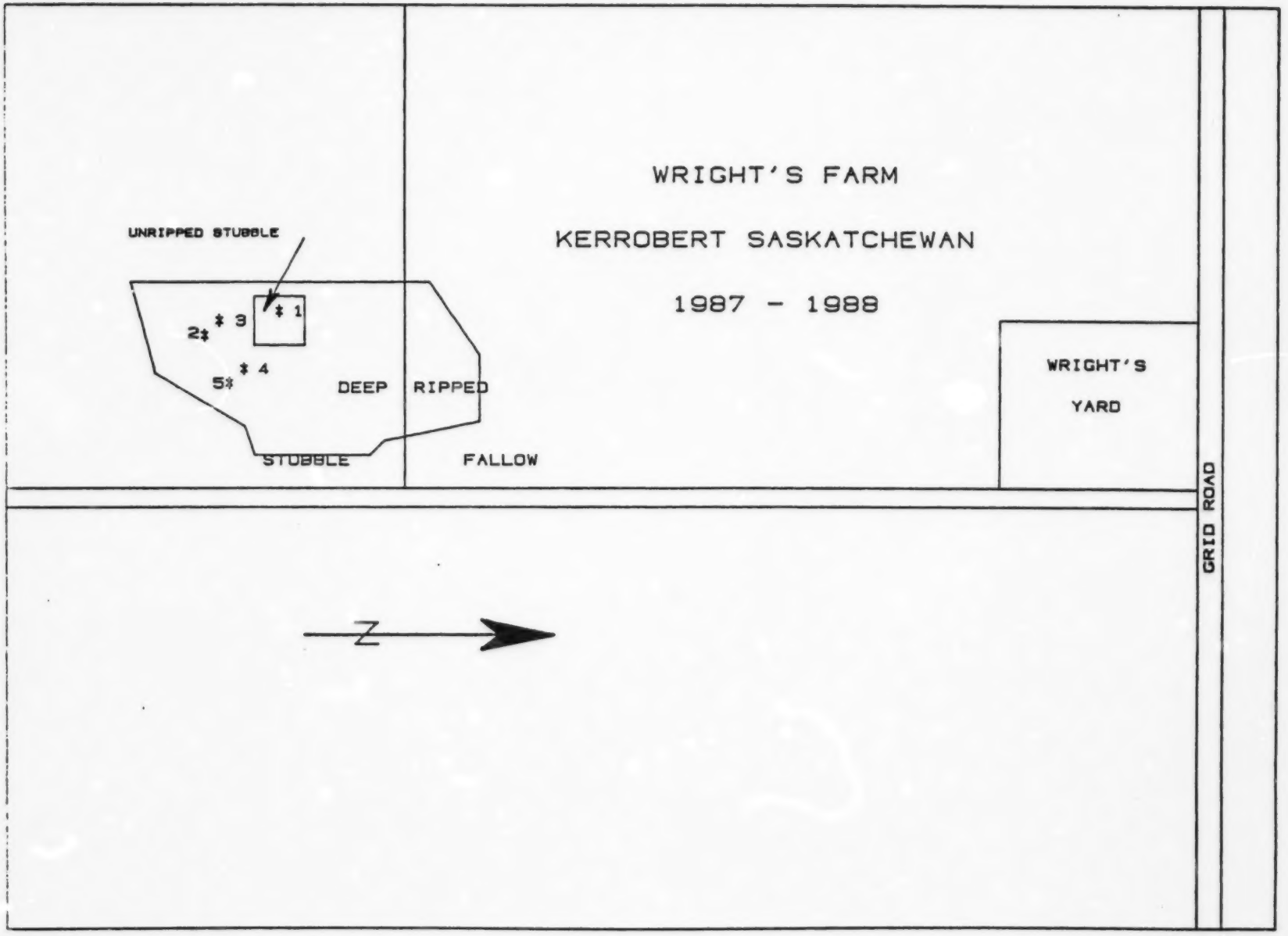

Figure 3: Soil moisture monitoring sites - Wrights Farm Kerrobert, 1987/88.

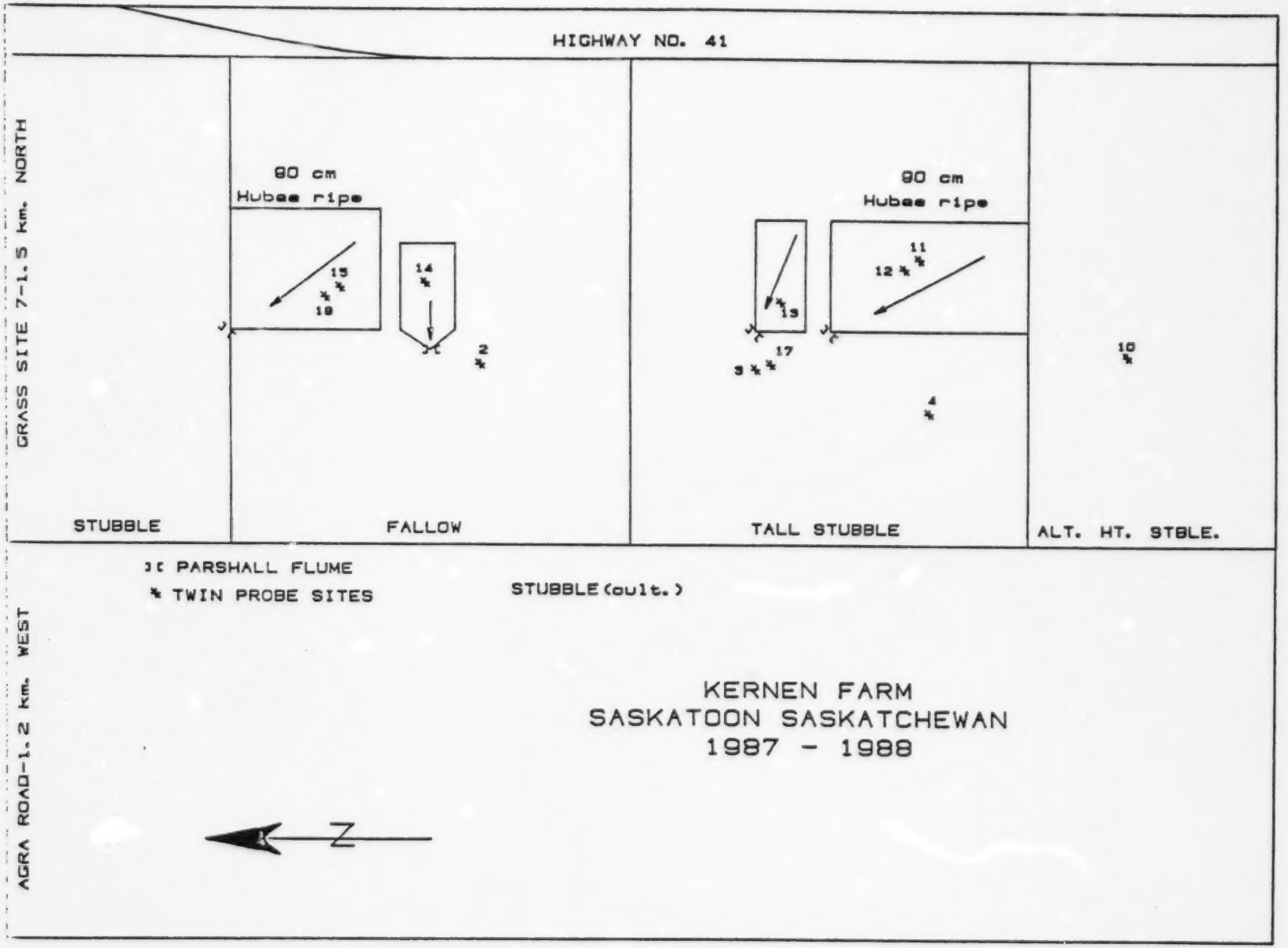

Figure 4: Soil moisture monitoring sites - Kernan Farm Saskatoon, 1987/88.

mm resulted in 137 and 105 mm of infiltration into the rips.

(b) Infiltrating meltwater penetrates to depths below the bottom of the rip and in cases with large amounts of infiltration occur the depth may exceed a rootzone depth of 1 m. A strong relationship exists between INF and d with INF increasing almost linearly with d, or vice versa. However, unless a snowcover is unusually deep (SWE > 150 mm; depth ≈ >60 cm), d is less than 1 m (average = 630 mm). This finding supports a recommended depth for lines of the order of 500 mm.

Table 1. Snowmelt infiltration to cracked and subsoiled soils, Kerrobert, Richlea, Saskatoon, 1988.

Site	No.[a]	Description	SWE (mm)	INF (mm)	d (mm)
Kerrobert					
Reynolds (w)	1	Ebson .7 (85)[b]	63	55.2	680
	7	Killefer (83)[c]	63	150.8	680
	8	Adjacent #7[d]	63	72.6	520
	9	Stubble[e]	60	68.3	520
	12	Kello .7 (86)[f]	43	28.4	280
	13	Kello 1.4 (86)[f]	60	100.7	780
	14	Adjacent #13	60	38.2	280
	15	Kello .7 (86)	57	121.2	760
	16	Kello 1.4 (86)	60	116.4	680
	17	Adjacent #16	66	103.4	600
	19	Kello 1.4 (86)	37	20.7	220
	20	Adjacent #19	31	15.3	140
	21	Kello .7 (86)	40	39.9	320
	24	Killefer (84)[c]	54	26.6	400
Reynolds (E)	1F	Adjacent #2	156	105.1	800
	2F	Hubee .9 (87)[g]	188	218.8	1240
	3F	Hubee .9 (87)	87	59.4	480
	4F	Adjacent #3	101	51.7	350
	5F	Hubee .9 (87)	194	194.2	1120
	6F	Adjacent #5	182	165.5	1240
	7F	Hubee .9 (87)	115	161.3	1000
	8F	Adjacent #7	153	128.2	880
	9	Stubble	15	9.5	160
	10	Stubble	13	10.8	300
	11F	Hubee .7 (87)[g]	146	109.3	960
	12F	Adjacent #11	186	83.0	880
	13F	Hubee .7 (87)	138	123.4	720
	14F	Hubee .7 (87)	166	104.7	760

	15F	Adjacent #14	177	102.2	600
	16F	Hubee .7 (87)	132	114.9	760
Wright's	1	Stubble	43	57.4	300
	2	Kello 1.4 (86)	45	138.7	640
	3	Adjacent #2	49	70.0	480
	4	Adjacent #5	47	85.6	480
	5	Kello 1.4 (86)	49	104.8	600
Richlea					
	1	Fallow	47	53.0	760
	2	Stubble	13	35.1	600
	6	Stubble	34	26.3	140
	7	Stubble[h]	80	154.7	480
Saskatoon					
	3	Stubble	100	37.8	180
	4	Stubble	140	58.4	560
	11	Adjacent #12	78	39.4	400
	12	Hubee .9 (87)	78	76.8	400
	13	Stubble	100	49.8	320
	14	Fallow[g]	48	84.0	400
	15	Hubee .9 (87)	48	85.8	600
	18	Adjacent #15	48	50.5	560

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[a] F = site was ringed by a snow fence

[b] Ebson .7 (85) = lines installed with Ebson plow in fall, 1985; depth = 400 mm, spacing = 0.75 m

[c] Killefer (83), Killefer (84) = lines constructed with Killefer plow in 1983 and 1984, respectively; depth = 600 mm; spacing 1.9 m

[d] Adjacent #7 = measurement of moisture change made in a soil column located 150 - 450 mm immediately adjacent to rip in which site No.7 is located

[e] Stubble = undisturbed stubble

[f] Kello .7 (86) and Kello 1.4 (86) = lines constructed with Kello-bilt plow in 1986 on line spacings of 0.7 and 1.4 m, respectively

[g] Hubee 0.7 (87) and Hubee 0.9 (87) = lines installed with Hubee subsoiler to a depth of 500 mm in 1987 on spacings of 0.70 and 1.4 m respectively

[h] soil crack.

Table 2. Average amounts of snowmelt infiltration to cracks, rips and uncracked/undisturbed soils for different ranges of snowcover water equivalent (INF).

SWE	INFILTRATION[a] Uncracked mm	Crack mm	Ratio	INFILTRATION[b] Undisturbed mm	Rips mm	Ratio
<30	12.4 (5)[c]	49.7 (2)	4.0	10.2 (2)	57.1 (3)	5.6
30-50	18.6 (7)	70.7 (2)	3.8	13.7 (3)	89.4 (4)	6.5
50-70	23.7 (11)	84.1 (9)	3.5	17.8 (d)	99.7 (7)	5.6
70-100	28.0 (23)	95.7 (5)	3.4	21.5 (8)	117.1 (5)	5.4
100-150	30.5 (17)	116.6 (9)	3.8	23.0 (d)	134.4 (9)	5.8
>150	34.5 (9)	147.0 (4)	4.3	27.6 (4)	154.9 (12)	5.6
		Mean	3.8		Mean	5.8

a Values given for cracked and uncracked soils are from all regions in Brown and Dark Brown soil zones of the Province in which soil cracking was observed. The major soil types are heavy clay and clay loam.

b Values for subsoiled and undisturbed soil are for Kerrobert where the principal soil texture is a glacial clay loam. The subsoiling treatments included: (a) Killefer plow - depth = 600 mm, spacing = 1.9 m; (b) Ebson plow - depth = 400 mm, spacing = 0.75 m; (c) Kello-bilt plow - depth = 600 mm, spacings = 0.70 and 1.4 m; (d) Hubee subsoiler - depth = 500 mm, spacings = 0.70 and 0.90 m.

c Values in parentheses refer to the number of samples

d Estimated values. The soil in the Kerrobert region exhibits some solonetzic characteristics, with infiltration to undisturbed stubble being consistently lower than at other locations in the Province by an approximate factor of 0.75.

3. Adjacent to a Crack or Rip

Infiltration into the soil column immediately adjacent to a rip or crack is less than that into the aperture, but greater in amount to that into undisturbed stubble. This can be attributed to the increased hydraulic conductivity of the soil mass caused by lateral rupture and fracture of the soil during installation of the lines and to the rip or crack acting as a source of water for lateral movement. Note the data in Table

demonstrate a close relationship between the amounts of meltwater entering a rip and adjacent soil.

The findings (Table 1) are combined with information collected in previous years and summarized as average amounts of snowmelt infiltration to cracks, rips and undisturbed sites for different ranges of snowcover water equivalent in Table 2. The data show INF increasing with SWE in both cracks and the rips with a trend for the rips to infiltrate more water than the "cracks". However, the ratio of the amount of infiltration into an opening to the amount infiltrating the same soil in undisturbed condition varies only slightly with SWE, on cracked soils the range in ratio - values varied between 3.4 and 4.3 with a mean of 3.8 and on "ripped soil between 5.4 and 6.5 with a mean of 5.8.

Figure 5 shows grouped mean values of soil water changes due snowmelt infiltration monitored in rips, cracks, adjacent to rips and undisturbed stubble plotted against snowcover water equivalent. Expressing these relationships in equational form gives:

Rips

$$INFR = 16.86\ SWE^{0.432.} \qquad [1]$$

Cracks

$$INFC = 8.48\ SWE^{0.553.} \qquad [2]$$

Adjacent to Rips

For SWE < 80 mm

$$INFA = 1.65\ SWE, \text{ and} \qquad [3a]$$

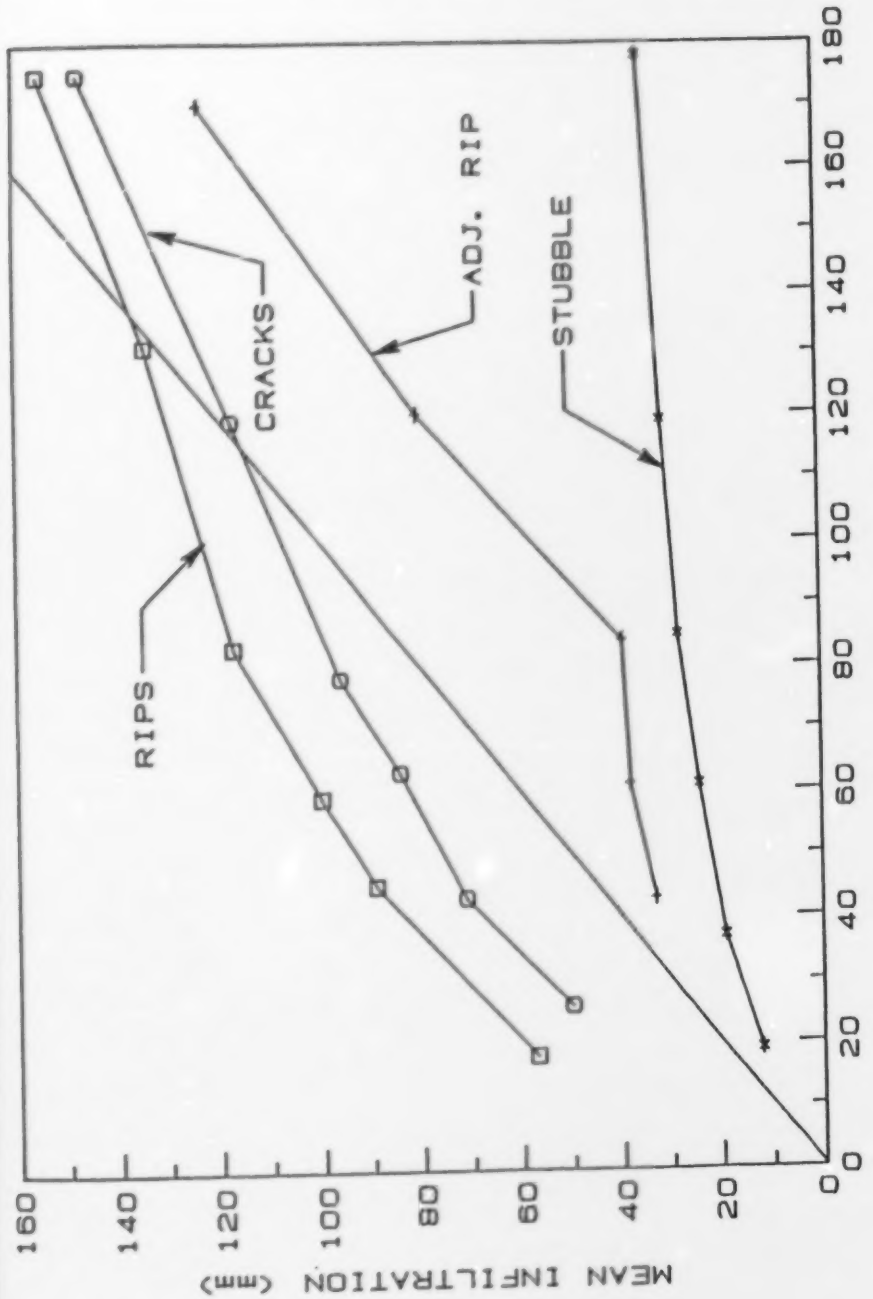

Figure 5: Average amounts of snowmelt infiltration (mm) into cracks, rips, adjacent to rips and undisturbed stubble as a function of average depth of snow cover water equivalent.

For SWE > 100 mm

$$INFA = -27.5 + 0.89\ SWE. \qquad [3b]$$

Undisturbed Soils

$$INF = 5.0(1 - \theta_p)SWE^{0.584}, \text{ and} \qquad [4]$$

where: INFR = infiltration into a rip, INFC = infiltration into a crack, INFA = infiltration into the soil column lying 150 to 450 mm adjacent to a rip, INF = infiltration into undisturbed soil, and SWE = snowcover water equivalent are in mm. θ_p = average premelt soil water (ice) content of the 0 -300 mm soil layer expressed as a degree of saturation (mm^3/mm^3.

Spacing of Rips

Equations 1 to 4 are be used as formulations for the development of a simple, conceptual
model describing the interaction between the average depth of snowmelt infiltration over a subsoiled field (INF(areal)) as a function of SWE and line spacing (s). Consider a soil which has been subsoiled with only minor disturbance to the structure of the mass confined between the rips. The system can be represented by three individual soil blocks (rip, adjacent to rip, and undisturbed (see Fig. 5)), each having its own infiltration characteristics. Taking the widths of the "rip" and "adjacent" blocks equal to the width of measurenment of soil moisture changes, ≈ 300 mm, the water balance equation can be written as:

$$INFR(areal) * s = INFR * 0.3 + INFA * 0.6 + INF * (s - 0.9), \qquad [5]$$

in which s is in metres. Substituting the expressions for INFR, INFA and INF given by Eqs. 1 - 4 into Eq. 5 and solving gives:

$s \geq 0.9$ and $SWE \leq 70$ mm

$$INF(areal) = (5.06SWE^{0.542} + 0.99SWE + (s - 0.9)[5(1 - \theta_p)SWE^{0.685}])/s \quad [6a]$$

$s \geq 0.9$ and $SWE \geq 100$ mm

$$INF(areal) = (5.06SWE^{0.542} - 16.5 + 0.534SWE + (s - 0.9)[5(1 - \theta_p)SWE^{0.685}])/s \quad [6b]$$

For snowcovers with 70 mm $\leq$ SWE $\leq$ 100 mm, the lesser amount of INF(areal) given by Eqs. 6a or 6b is used.

Equations 6a and 6b are plotted for a range of SWE-values and two levels of "Premelt" soil moisture ($\theta_p = 0.4$ and $\theta_p = 0.6$) in Figs. 6 and 7. Also plotted in the figures is INF(areal) for rips spaced at 0.7 m and for undisturbed soil. To demonstrate the application of the curves assume average annual snowfall water equivalents of 90 to 125 mm, respectively and trapping efficiencies of snow management practices in the range of 60 to 75% of annual snowfall. Table 3 shows that in soils which are normally dry in the fall, lines should be spaced between 0.7 and 1.3 m, depending on SWE and in soils that are usually wet in the fall line spacings of 0.9 m or less should be used. The depth

Table 3. Spacings of rips in (m) for annual snowfall water equivalents of 90 and 125 mm, trapping efficiencies of 60 and 75% and two levels of "Premelt" soil moisture, $\theta_p = 0.4$ and $\theta_p = 0.6$.

Snowfall Water Equivalent (mm)	Trapping Efficiency (%)	Premelt Soil Moisture ($\theta_p = 0.4$)	($\theta_p = 0.6$)
90	60	1.3	0.9
90	75	1.05	0.7
125	60	0.95	<0.7
125	75	<0.7	<0.7

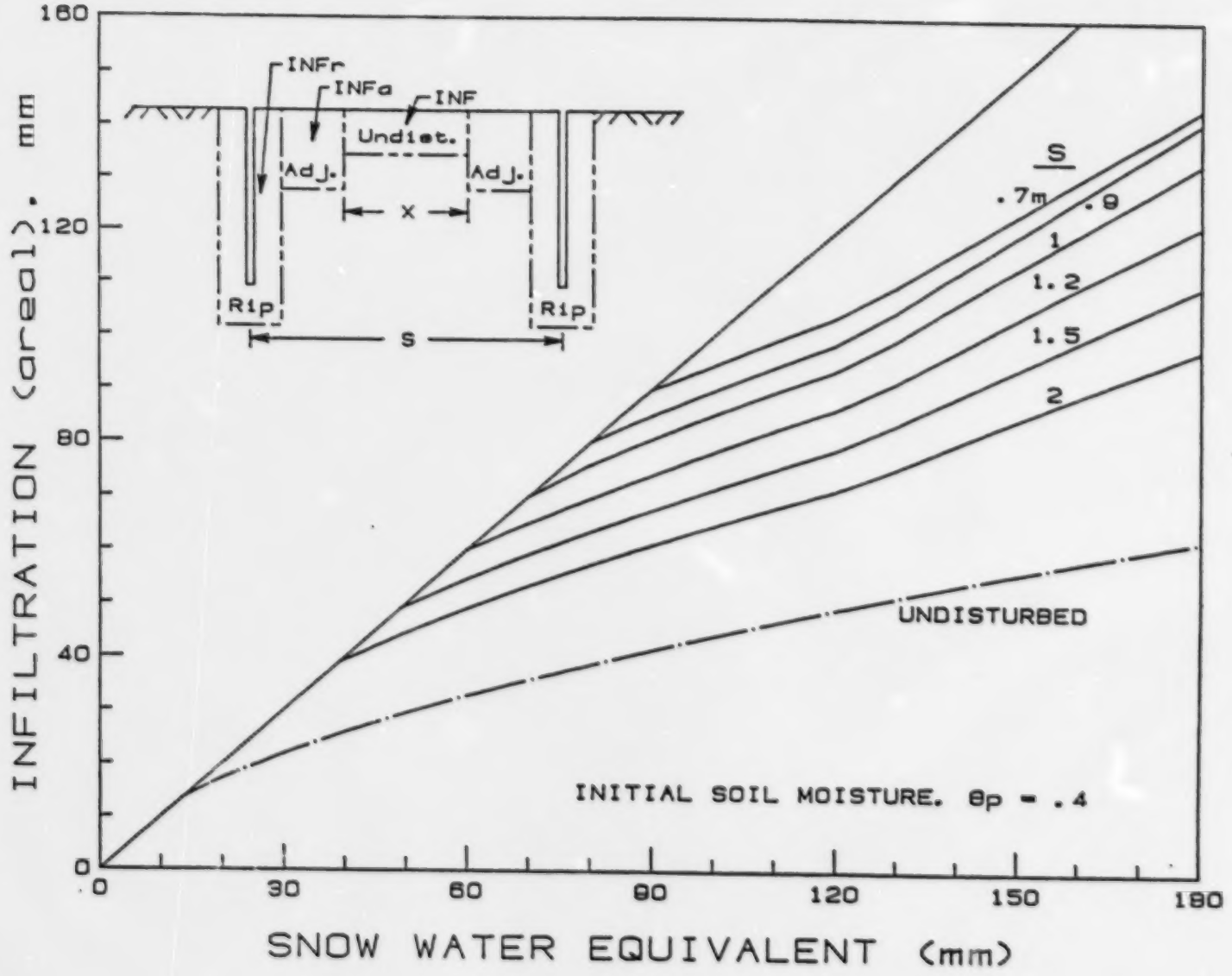
INFILTRATION (areal), mm
SNOW WATER EQUIVALENT (mm)
INFr
INFa
INF
Undist.
Adj.
Adj.
x
Rip
Rip
s
S
.7m
.8
1
1.2
1.5
2
UNDISTURBED
INITIAL SOIL MOISTURE. θp = .4
0
40
80
120
160
0
30
60
90
120
150
180

Figure 6:

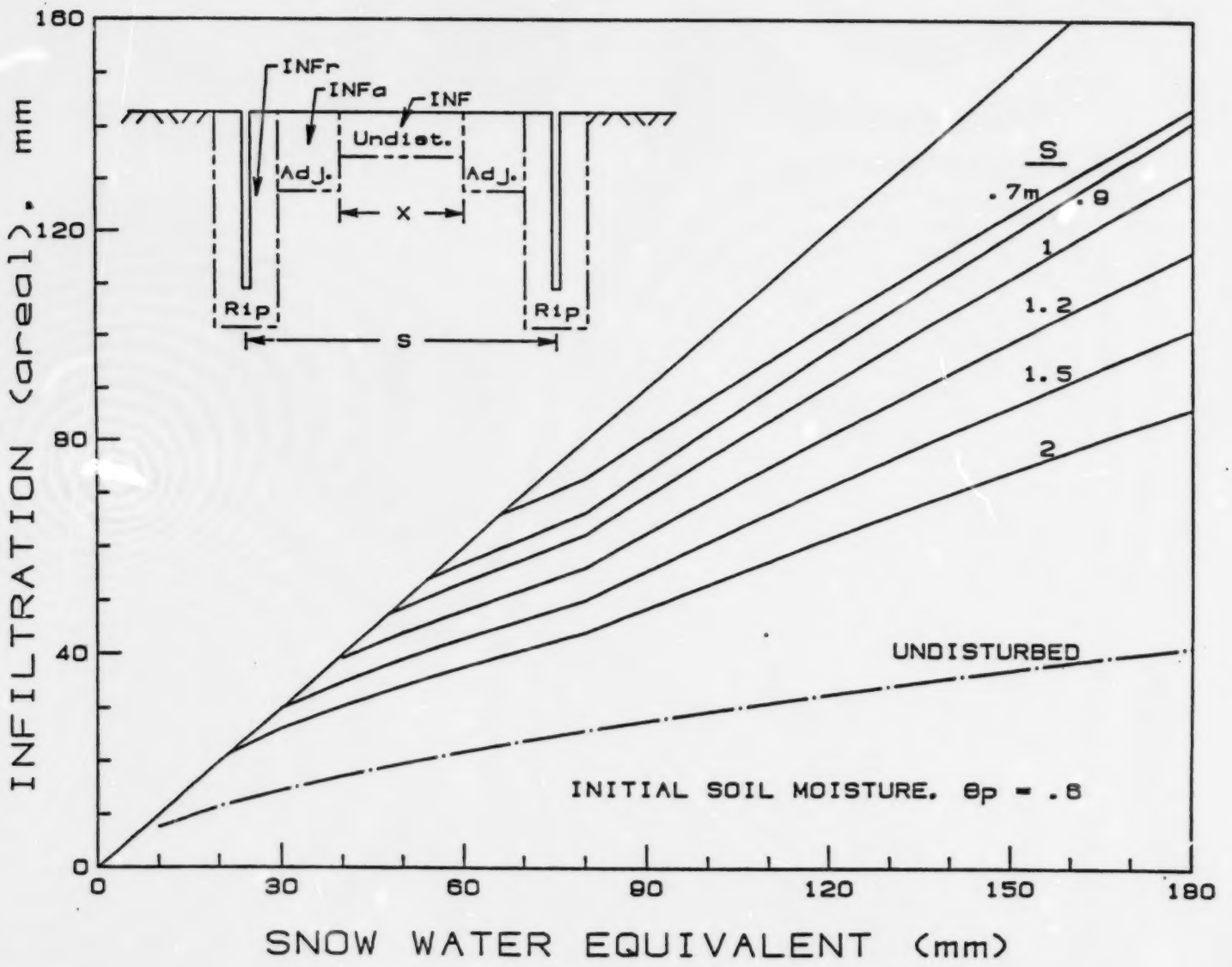
INFILTRATION (areal), mm
SNOW WATER EQUIVALENT (mm)
INFr
INFa
INF
Undist.
Adj.
Adj.
x
Rip
Rip
s
S
.7m
.9
1
1.2
1.5
2
UNDISTURBED
INITIAL SOIL MOISTURE, θp = .6
0
40
80
120
160
0
30
60
90
120
150
180

Figure 7:

of a "normal" snowcover with a water equivalent of 54 mm, the smallest value of available soil water used in the calculations of Table 3 (0.60 * 90 mm), is of the order of 22 cm. For shallower snow depths, the line spacing can be increased. For example, lines spaced between 1.3 or 2.2 m would infiltrate 15 cm of snow, depending on soil wetness.

The model can be expected to give reasonable predictions of areal infiltration in the first year of subsoiling in cases when the subsoiling operation has not produced substantial lateral fracturing of the mass of soil confined between the "rips". It is limited to these cases because the expression for infiltration to "undisturbed" soil (Eq. 4) does not describe the process for disturbed soils. Comparisons between measured and calculated areal infiltration amounts are given in Fig. 8. "It is suspected that if lines are installed at spacings less than 0.7 m, most commercially-available subsoilers will disturb and rupture the mass of soil between the rips to such an extent that, at least in the first year, they will have the capacity to infiltrate all water from those snow accumulations which are likely to be trapped by a stubble management practice <36 cm), independent of the soil moisture content". It can be expected that the infiltration potential of a subsoiled soil will naturally decrease in time due to settlement and packing. However, field observations suggest that the beneficial effects of a subsoiling treatment on meltwater enhancement may be "longer lasting" in rips placed at wider spacings to some maximum due to natural cracks which develop between the lines in response to strong gradients in soil moisture caused by differential withdrawal patterns.

Based on the evidence collected to date it is suggested that subsoiling to a depth between 400 - 500 mm on a line spacing between 0.9 and 1.2 m is adequate to allow efficient meltwater augmentation from a snow (stubble) management practice in most glacial till soils in the Province under normal snowfall and soil moisture conditions. For slightly solentetzic soils the spacings should be decreased slightly. These criteria are supported by visual observations of crop growth. With lines spaced at 1.4 m and wider crop growth and maturity is nonuniform, the plants directly over the lines are taller and mature more slowly.

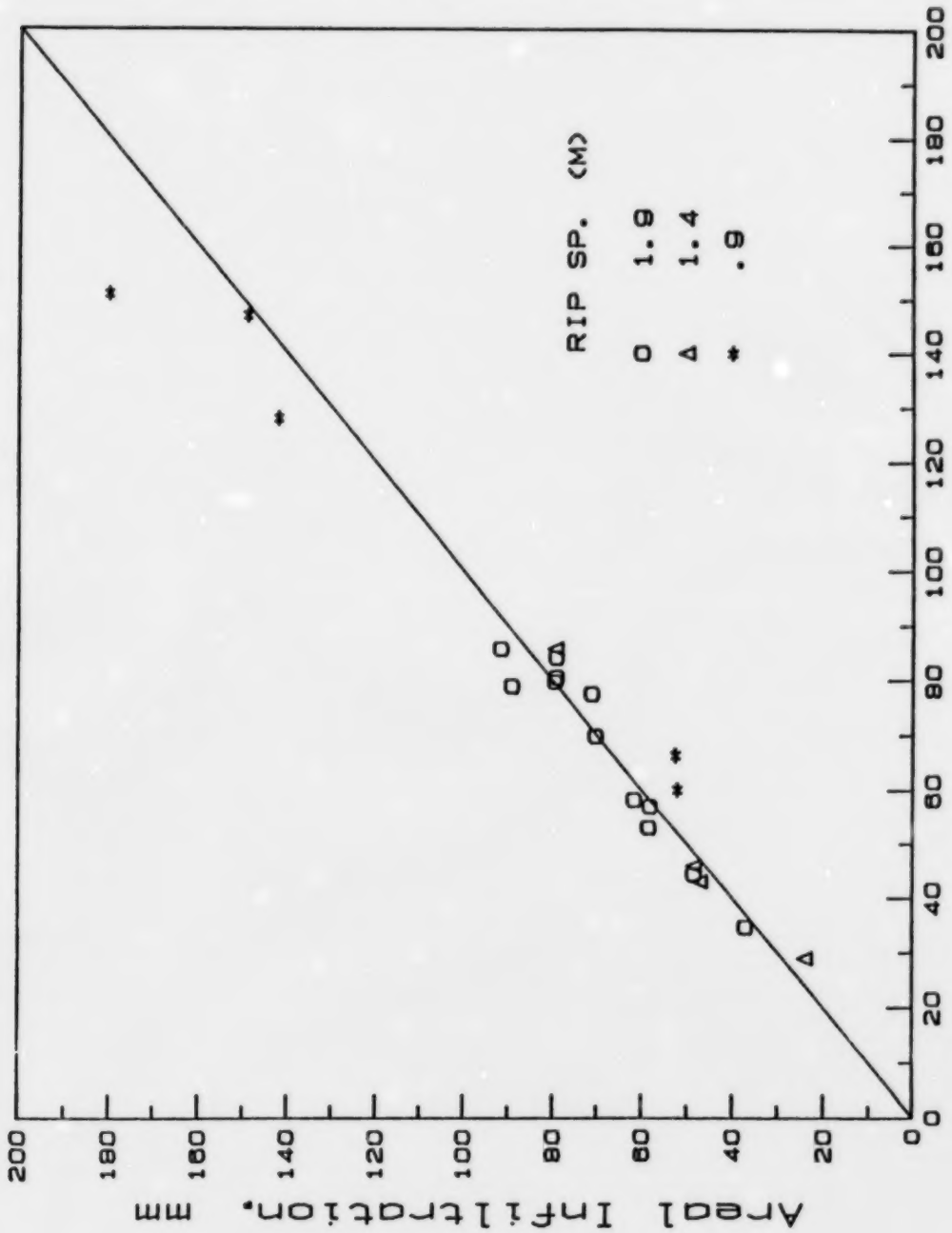
Areal Infiltration, mm
Calculated Areal Infiltration, mm
RIP SP. (M)
o 1.8
Δ 1.4
* .9
0
20
40
60
80
100
120
140
160
180
200

Figure 8:

EFFECTS OF SNOW MANAGEMENT AND SUBSOILING ON CROP YIELD

An important goal of the study is to obtain information on the effects of snow management and subsoiling practices on crop yield. Yield data can also be used to index the longevity of the treatment effects.

For the 1987-88 season at the Kerrobert sites, the subsoiled plots were in 2nd-year stubble and, because of the patchy snowcover no supplemental fertilizer the plots. Also the patchy growth and poor stand of the wheat crop negated meaningful yield data from total plot areas. As a consequence, samples were taken with a small-plot combine (Wintersteiger) at selected locations on the fields so as to provide yield information over the range of observed snowcover water equivalents. Figure 9 shows the increase in yield with increased snowmelt infiltration relative to the yield from undisturbed stubble plots showing the lowest yield. The soil water increases for the subsoiled areas were estimated using the observed snowcover water equivalents and the model for areal infiltration to subsoiled sites, or from infiltration amounts observed at soil moisture monitoring sites located at or near to the sites where the combine samples were taken. The best-fit line through the data (taken through the origin) indicates that each additional 25 mm of water produces a yield increase of about 190 kg/ha of spring wheat. There was no discernable difference in yields from areas subsoiled on .7 m and .9 m spacings.

The data in Table 4 show the effects on yield of subsoiling treatments without snow management. They show a decrease in treatment effect on yield with time. In the first two years following installation the change is small; in the first year there is an average difference of 435 kg/ha compared to the yield from undisturbed stubble (34% increase), while in the second year a difference of 377 kg/ha (30% increase) is observed. In the fourth year the difference has been reduced to 20 kg/ha (only 1% increase). It is mentioned however, that this small residual effect in the fourth year is likely due, at least in part, to the low amount of precipitation (snow and rain) received in 1987, the only year with fourth year data. Over the life of the trials the average annual prcipitation has been less than normal.

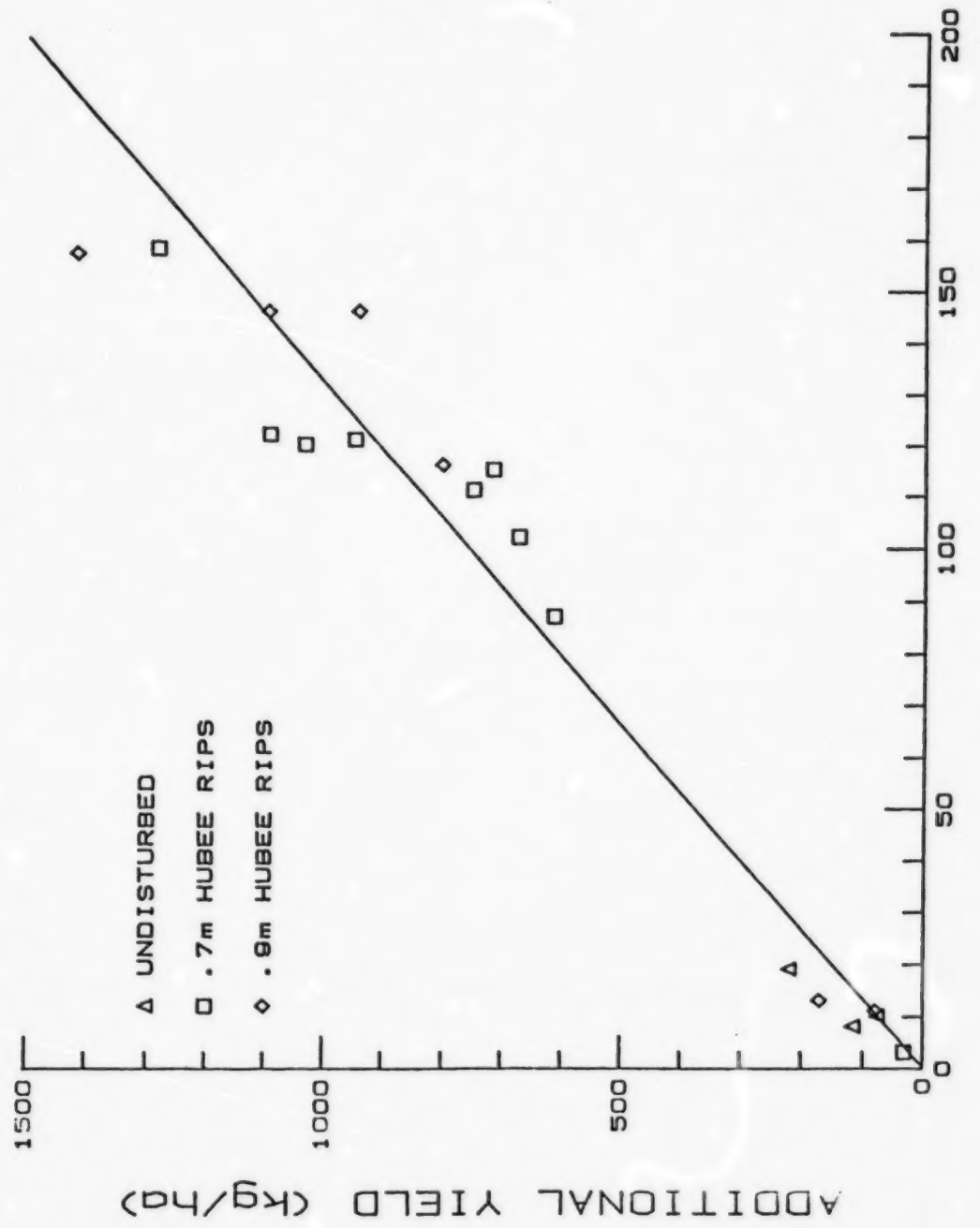
ADDITIONAL YIELD (kg/ha)
1500
1000
500
0
0
50
100
150
200
ADDITIONAL MOISTURE (mm)
△ UNDISTURBED
□ .7m HUBEE RIPS
◇ .9m HUBEE RIPS

Figure 9:

Table 4. Effect of subsoiling on the yield of spring wheat without snow management and supplemental additions of fertilizer.

Landuse and Age of Rips	SWE[a] mm	Rain[b] mm	Yield (kg/ha) Difference	Ratio[d]	Range in Ratio
Fallow[e]		110	610	1.44	1.05 - 1.71
Stubble Rips					
1st year	52	110	435	1.34	1.18 - 1.60
2nd year	50	122	377	1.30	1.18 - 1.52
3rd year	42	122	132	1.11	1.06 - 1.15
4th year	26	100	20	1.01	1.01

a Mean snowcover water equivalent.
b Average growing season rainfall.
c Difference in yield from that on stubble (1-year rotation).
d Ratio of mean yield on treatment to that on stubble.
e 4-year average yield from crop on fallow without snow management was 1896 kg/ha.

SWIFT CURRENT SITES

At the Swift Current sites, the objective of the studies and the results are as follows:

1. **Experiment No 1: Swift Current (John Warkentin Farm)**

Objectives:

(1) To determine the effects of different subsoiling treatments and snow management on meltwater infiltration, soil water distribution within the crop rooting zone, and continuous wheat yields.

(2) To study the effects of subsoiling and snow management on nitrate leaching and nitrogen mineralization.

(3) To evaluate the economic benefits of snow management and different subsoiling treatments.

(4) To determine if additional nitrogen is required to make full benefit of conserved water from subsoiling and snow management.

Progress/Results:

Enhanced soil water evaporation from the furrows of the 1987 subsoiling treatments was evident as early as late fall 1987 (Table 5). Evaporation from the 1986 subsoiling treatments was similar to the nonsubsoiled control treatment. There was very little snow accumulation (Table 6) which, combined with relatively warm temperatures, resulted in the low overwinter soil water gains. The 1987 subsoiling treatments lost almost all precipitation received between fall and spring soil water measurements. The control treatments had more available water than any of the 1986 or 1987 subsoiling treatments. Despite minimal precipitation between early spring and seeding, little soil water was lost during that period.

All plots were cultivated to prepare a seedbed just before seeding (May 7th, 1988).

Table 1. Mean fall to spring available soil water (mm > 40b) for 0-1.2m.

Treatment	Fall 87/11/10	Spring 88/04/11	Spring-Fall	Seeding 88/05/07	Seeding-Spring
Snow Management					
Control	41 A	59 A	18 ABC	55 A	-4 AB
Chisel Plow 1986	33 A	55 A	21 AB	50 AB	-4 A
Paraplow 1986	27 AB	52 AB	26 A	50 AB	-2 ABC
Chisel Plow 1987	10 B	18 E	7 CD	18 C	0 ABC
Hubbee 1987	23 AB	27 CDE	4 D	28 BC	1 C
Kello-Bilt 1987	19 AB	23 DE	4 D	23 C	0 ABC
Paraplow 1987	24 AB	29 CDE	5 CD	29 BC	0 ABC
Mean	25	38	12	36	-1
Conv. Stubble					
Control	35 A	45 ABC	10 BCD	46 AB	1 BC
Chisel Plow 1987	22 AB	32 BCDE	10 BCD	30 BC	-2 ABC
Hubbee 1987	35 A	40 ABCD	5 CD	37 ABC	-3 AB
Mean	31	39	8	38	-1

Note: Means within columns followed by the same upper case letter are not significantly different (5% level).

Table 6. Snow Survey: February 16/88

Treatment	Snow Management snow depth (cm)	Snow Management water equivalent (cm)	Conventional Stubble snow depth (cm)	Conventional Stubble water equivalent (cm)
Control	15	4.0	7	1.7
Chisel Plow 1986	14	3.8	-	-
Paraplow 1987	16	4.1	-	-
Chisel Plow 1987	8	2.1	2	0.4
Hubbee 1987	6	1.7	5	1.0
Kello-Bilt 1987	8	2.1	-	-
Paraplow 1987	8	2.0	-	-
Mean	11	2.8	5	1.0

By July 25 (the approximate average date of heading across all plots, the wheat had consumed most available soil water on all treatments and the soil water advantage of the control and 1986 treatments over the 1987 treatments had disappeared (Table 7). Soil water at harvest was slightly greater than at heading. Soil water use from seeding to harvest was very small for all 1987 subsoiling treatments.

Table 7. Mean seeding to harvest available soil water (mm > 40b) for 0-1.2m.

Treatment	Seeding 88/05/07	Heading 88/07/25	Seeding-Heading	Harvest 88/08/17	Seeding-Harvest
Snow Management					
Paraplow 1987	29 BC	16 A	13 D	22 A	7 B
Control	55 A	13 A	42 A	16 A	39 A
Paraplow 1986	50 AB	13 A	38 ABC	18 A	32 A
Chisel Plow 1986	50 AB	11 A	40 AB	11 A	39 A
Chisel Plow 1987	18 C	6 A	12 D	9 A	8 B
Hubbee 1987	28 BC	11 A	18 CD	17 A	11 B
Kello-Bilt 1987	23 C	9 A	14 D	17 A	6 B
Mean	36	11	25	16	20
Conv. Stubble					
Control	46 AB	20 A	25 ABCD	20 A	26 AB
Chisel Plow 1987	30 BC	15 A	15 D	19 A	11 B
Hubbee 1987	37 ABC	16 A	21 BCD	25 A	12 B
Mean	38	17	20	21	16

Note: Means within columns followed by the same upper case letter are not significantly different (5% level).

There was no significant grain yield response to snow management practices (Table 8). The mean yield of the 1987 subsoiling treatments was significantly less than the mean yield for the 1986 subsoiling treatments and also significantly less than the control. There were no yield differences between subsoiling treatments of the same year nor between the mean of the 1986 subsoiling treatments and the control. Grain yields were positively correlated with available soil water at seeding.

Based on fall soil test results, the fertilizer rate (expressed in actual N) was 39 kg/ha and 67 kg/ha for normal moisture and above normal moisture conditions, respectively. There was no grain yield response to additional fertilizer (Table 8).

Analysis of core bulk densities taken in May, 1988 showed no treatment effect on soil bulk density.

Table 8. Spring Wheat Grain Yields (kg/ha).

Treatment	Normal N	Above-Normal N	Mean
Snow Management			
Paraplow 1987	287 BCD	248 CD	267 BC
Control	412 A	392 AB	402 A
Paraplow 1986	392 AB	421 AB	406 A
Chisel Plow 1986	362 ABC	440 A	401 A
Chisel Plow 1987	246 D	216 CD	231 C
Hubbee 1987	207 D	191 C	199 C
Kello-Bilt 1987	225 D	235 CD	230 C
Mean	304	306	305
Conv. Stubble			
Control	378 ABC	322 BC	350 AB
Chisel Plow 1987	251 D	228 CD	240 C
Hubbee 1987	207 D	191 D	254 BC
Mean	301	262	282
Orthogonal Contrasts (snow management plots)			
PP & CP 1986	377 A	430 A	403 A
PP & CP 1987	267 B	232 B	250 B
Control	412 A	392 A	402 A
1987 treatments	241 B	222 B	231 B

Note: Means within columns followed by the same upper case letter are not significantly different (5% level).

Standard cone penetrometer readings were obtained on October 21, 1988 on Experiment No. 1 (Table 9). There were significant differences between treatments at similar depths down to a depth of 40 cm. The treatments were divided into 3 categories: control treatment with high average soil penetration resistance, 1986 subsoiling treatments with intermediate soil penetration resistance, and 1987 subsoiling treatments with lowest soil penetration resistance. The effects of subsoiling on soil resistance were obvious. Comparing soil resistance for 1986 and 1987 subsoiling treatments suggested the soil was reconsolidating over time and returning to the nonsubsoiled soil resistance.

Table 9. Penetrometer Measurements (Newtons)

Subsoiling Treatments (subsoiling depth, cm)

DEPTH (cm)	CNTL	CP 1986 (25)	PP 1986 (35)	CP 1987 (25)	HB 1987 (38)	PP 1987 (35)	KB 1987 (53)
2	140	109	119	90	88	110	118
6	364	361	360	178	176	217	235
10	571	453	450	226	260	291	334
14	624	451	452	283	345	340	353
18	635	493	494	350	350	288	399
22	613	563	554	550	339	327	366
26	603	593	569	673	404	377	293
30	619	560	513	635	409	369	337
34	594	556	466	582	459	414	325
38	595	569	540	597	513	484	336
42	661	557	600	633	577	575	413
46	703	662	615	678	581	650	497
50	757	579	677	719	638	607	713
Mean	561	490	488	468	391	377	352
Mean	561	489		397			

Notes: 1) Each measurement in the table represent the average force over a span of 2 cm. The means were determined from additional data not shown in the table.

2) The control, Chisel Plow 1987 and Hubbee 1987 forces represent the average between snow trapping and conventional stubble treatments.

The Deutz Fahr DX 6.50 was instrumented to monitor fuel consumption, engine rpm, front wheel speed, and % slip of the rear driving wheel. Information was collected on Experiment No. 1 while the 1987 treatments were being placed (Table 6). Because of problems with the fuel consumption meter we were unable to collect fuel consumption with the Hubbee subsoiler. Fuel consumption per unit area increased rapidly with increasing subsoiling depth.

Table 10. Subsoiler work rates and fuel use.

Subsoiler	Width m	Depth cm	Fuel L/h	Speed km/h	Slip	ha/h	L/h	L/ha
Paraplow	1.5	35	21.2	5.4	0.24	0.65	32.6	50
Chisel Plow	3.0	25	16.0	3.9	0.25	0.94	17.0	18
Kello-Bilt	2.2	53	14.5	2.2	0.27	0.39	37.2	95
Hubbee	2.9	38	-	3.6	0.33	0.84	-	-

Notes: 1) Engine RPM = 2100.
2) ha/h, L/h and L/ha are based on a field work efficiency rate of 80%

2. Experiment No. 2: Swift Current (John Warkentin Farm)

Objectives:

(1) To evaluate the effects of several subsoiling treatments on meltwater infiltration and wheat yields for different slope positions.

(2) To evaluate the economic benefits of subsoiling and snow management for rolling land.

Progress/results:

All plots were cultivated to prepare a seedbed prior to seeding (may 8, 1988).

As in 1987, soil water varied with slope position (Table 11). Additional access tubes were placed along the slope and at each position after seeding to improve analysis of changes in the moisture profile that were encountered in 1987.

There was no treatment effect on overwinter soil water gain. Within treatments the upper slope positions retained more available soil water than the lower slope positions. The treatment*slope position interaction was not significant at any one date which indicated the slope effect on soil water was the same for all treatments. On the toe slope, the control had more available water in fall, 1987 and early spring, 1988 but additional water was consumed by wheat seedlings soon after emergence.

Table 11: Available soil water (mm > 40 b) for 0-1.2m.

Date	Treatment	Slope Position A	B	C	D	E	Mean
87/11/04	Control	49 A	-	23 A	-	48 A	40
(Fall)	Hubbee	66 A	-	19 A	-	6 B	31
	Kello-Bilt	70 A	-	35 A	-	11 B	38
	Mean	62		26		22	36
88/04/07	Control	57 A	-	33 A	-	62 A	51
(Early	Hubbee	74 A	-	32 A	-	25 AB	44
Spring)	Kello-Bilt	79 A	-	48 A	-	23 B	50
	Mean	70		38		36	48
88-04-29	Control	48 A	-	30 A	-	60 A	46
	Hubbee	68 A	-	29 A	-	22 AB	40
	Kello-Bilt	75 A	-	44 A	-	20 B	46
	Mean	64		34		34	44
88/05/17	Control	56 A	67 A	14 A	27 A	30 A	39
	Hubbee	68 A	73 A	23 A	31 A	23 A	44
	Kello-Bilt	68 A	70 A	35 A	34 A	30 A	47
	Mean	64	70	24	31	28	43
88/07/26	Control	32 A	42 A	-7 A	6 A	13 A	17
(Heading)	Hubbee	48 A	49 A	1 A	13 A	5 A	23
	Kello-Bilt	46 A	46 A	5 A	15 A	20 A	27
	Mean	42	46	0	11	13	22
88/08/23	Control	25 A	37 A	1 A	14 A	27 A	21
(Harvest)	Hubbee	40 A	42 A	5 A	28 A	15 A	26
	Kello-Bilt	39 A	41 A	6 A	29 A	31 A	29
	Mean	35	40	4	24	25	25

Notes: 1) Means within columns (of the same date) followed by the same letter are not significantly different (5% level).

2) A = upper slope B = upper-mid slope C = mid slope
D = mid-toe slope E = toe slop

A grain yield trend versus slope position was calculated from grain yield measurements every 3.5m along the slope (Figure 10). The treatment*slope position interaction was not significant indicating that the slope effect was the same for each treatment. When yields were averaged over the entire plot, the yields for the Kello-Bilt treatment (460 kg/ha) and control (458 kg/ha) were significantly larger than the Hubbee treatment (398 kg/ha). In a complete reversal from 1987 the upper slope position out yielded the lower slope positions. This was due in most part to late germination on the upper slope which allowed the wheat to benefit from later rains.

Fuel consumption, forvard speed, engine rpm, and slip was monitored on Experiment No. 2 as was done on Experiment No. 1 (table 12). The plots were subsoiled perpendicular to the slopes. There were no differences found between slope positions.

Table 12. Subsoiler work rates and fuel use.

Subsoiler	Width m	Depth cm	Fuel L/h	Speed km/h	Slip	ha/h	L/h	L/ha
Kello-Bilt	2.2	46	16.7	3.1	0.18	0.54	31	57
Hubbee	2.9	38	-	3.7	0.27	0.86	-	-

Notes: 1) Engine RPM - 2100.
2) ha/h & L/h are based on a field efficiency rate of 80%.

Analyses of core bulk densities taken in May 1988 showed no treatment effect.

3. Experiment No. 3: Swift Current (Agriculture Canada Research Station)

Objectives:

(1) To study the effect of different subsoiling treatments on meltwater infiltration and overwinter soil water movements.

(2) To study the durability of subsoiling effects on soil physical properties.

Progress/results:

Soil water was measured and analyzed by the Division of Hydrology, University of Saskatchevan.

All plots were cultivated to prepare a seed bed just prior to seeding (May 12, 1988).

There were no significant differences found between treatments for either grain yield of straw+chaff yields (Table 13). With the exception of the Hubbee treatment all other treatments out yielded the control treatment. The reason for the relatively poor wheat yields for the Hubbee treatment (which was also evident in Experiment No. 1 and No. 2) is unknown.

The better yield performance for Experiment No. 3 of the subsoiling treatments (with the exception of the Hubbee treatment) relative to the control contrasts markedly with the results from Experiment No. 1 (with very similar soils and topography as Experiment No. 3). This behavior was attributed to the greater water availability in Experiment No. 3 since considerable snov water was trapped by the snov fence enclosures. The yield response of the subsoiling treatments to the amount of available soil water in the spring was greater than that of the control.

Table 13. Grain and Straw+Chaff Yields.

	Yield (kg/ha)	
Treatment	Grain	Straw+Chaff
Kello-Bilt 1987	789 A	1776 A
Paraplov 1986	719 A	1422 A
Slot Mulch 1987	707 A	1385 A
Chisel Plow 1986	698 A	1385 A
Control	650 A	1339 A
Hubbee 1987	504 A	1165 A

Note: Means within columns followed by the same letter are not significantly different (5% level).

NHRI REPORT

FIGURE NUMBERS AND CAPTIONS

FIGURE/PAGE	
1/4	Soil moisture monitoring sites - Reynold's Farm (west), Kerrobert, 1987/88.
2/5	Soil moisture monitoring sites - Reynold's Farm (east, Kerrobert, 1987/88.
3/6	Soil moisture monitoring sites - Wright's Farm, Kerrobert, 1987/88.
4/7	Soil moisture monitoring sites - Kernan Farm, Saskatoon, 1987/88.
5/12	Average amounts of snowmelt infiltration (mm) into cracks, rips, adjacent to rips and undisturbed stubble as a function of average depth of snowcover water equivalent (mm).
6/15	Relation between "areal" infiltration, line spacing (s) and snow water equivalent for "dry" (premelt soil moisture = 0.40 mm^3/mm^3), subsoiled soils.
7/16	Relation between "areal" infiltration, line spacing (s) and snow water equivalent for "wet" (premelt soil moisture = 0.60 mm^3/mm^3), subsoiled soils.
8/18	Comparison between "measured" and "modelled" amounts of "areal" infiltration.
9/20	Yield - soil moisture interaction on undisturbed and subsoiled soils at Kerrobert expressed as increases above the lovest amounts observed on undisturbed stubble.

SNOW MANAGEMENT AND MELTWATER ENHANCEMENT
STATEMENT OF EXPENDITURES AND RECEIPTS

RECEIPTS:

ADVANCE ON SIGNING AGREEMENT - RECEIVED DECEMBER 19, 1986	$ 50,000.00
PAYMENT ONE - DECEMBER 1, 1986 RECEIVED MAY 5, 1986	$ 50,000.00
PAYMENT TWO - SEPTEMBER 1, 1987 RECEIVED FEBRUARY 9, 1988	$ 35,000.00
PAYMENT THREE - DECEMBER 1, 1987 RECEIVED FEBRUARY 9, 1988	$ 50,000.00
PAYMENT FOUR - MARCH 1, 1988 RECEIVED APRIL 8, 1988	$ 50,000.00
PAYMENT FIVE - SEPTEMBER 1, 1988 RECEIVED JANUARY 17, 1989	$ 35,000.00
PAYMENT SIX - DECEMBER 1, 1988 RECEIVED JANUARY 18, 1989	$ 50,000.00
TOTAL	$ 320,000.00

TOTAL EXPENDITURES (To March 2, 1989):

Labour (incl. soil analysis)	$ 212,030.57
Rentals	$ 21,497.55
Materials and supplies	$ 32,328.50
Other (travel, phone, computer time,etc.)	$ 53,644.46
Overcharge	$ 704.86
TOTAL	$ 320,205.94

BALANCE (Total receipts - Total Expenditures) $ - 205.94

PROJECTED EXPENDITURES (To March 31, 1989)

Salaries and benefits	$ 15,800.00
Materials and supplies	$
Equipment rental, etc.	$
Other (phone, computer)	$ 5,166.00
TOTAL PROJECTED	$ 20,966.00

PROJECTED RECEIPTS - March 1, 1989	$ 50,000.00
December 1, 1989	$ 35,000.00
	$ 85,000.00

BALANCE $ 64,004.00